

## **Participatory, explorative, qualitative modeling: application of the iMODELER software to assess trade-offs among the SDGs**

*Kai Neumann, Carl Anderson, and Manfred Denich*

### **Abstract**

The UN's Sustainable Development Goals (SDGs) in their generalized form need to be further reflected in order to identify synergies and trade-offs between their targets, and to apply them to concrete nations and regions. Explorative qualitative cause and effect modeling could serve as an approach for considering crucial factors to better understand the interrelations among the SDGs, eventually leading to more informed concrete measures that are able to cope with the SDG's inherent obstacles. This work describes a model that could serve as a template for concrete application. The generalized model already points to some potential trade-offs. Its first analysis cautiously raises doubts that some possible assumptions behind the SDGs might overlook systemic boundaries. For example, an undifferentiated increase of productivity contradicts a lessened environmental impact and need for resources in light of potential planetary boundaries. However, the model was developed as a starting point and requires modification for its application to a concrete region.

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### **Authors**

*Kai Neumann*, ilsa Consulting, Scharbeutz, Germany, [kai.neumann@ilsa-consulting.com](mailto:kai.neumann@ilsa-consulting.com)

*Carl Anderson*, Center for Development Research (ZEF), Bonn, Germany

*Manfred Denich*, Center for Development Research (ZEF), Bonn, Germany

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## **1 Introduction**

The UN's Sustainable Development Goals (SDGs) comprise 17 goals and their embedded 169 targets. They cover environmental (including resources and climate change), economic, and social sustainability; the complex interplay between which creates synergies as well as trade-offs. According to cognitive studies (Halford et al., 2005), when we are faced with a complex challenge we need the help of tools to grasp the interplay of four or more factors. To understand how we can transition towards a sustainable world community is a challenge for which we need to consider far more than four factors. Much research is still limited to only a few perspectives, generating prescriptions as to what needs to happen but with little explanation as to why something is not happening and what could thus be a lever for change. This paper features a qualitative cause and effect model that connects the targets of the SDGs in order to grasp their interplay, identify the levers for effective measures and their obstacles, and to serve as a tool for application within the environmental, economic and social context for regions and nations. Its simplicity is an advantage compared to quantitative approaches and yet it goes beyond other qualitative approaches.

## **2 Connecting the 17 SDGs and their 169 targets**

The 17 SDGs (United Nations, 2015) and their 169 targets have not yet been officially connected nor systemically analyzed in a both general and comprehensive manner. However, a quantitative simulation model called iSDG has been created by the Millennium Institute (<https://www.millennium-institute.org>) and it has been applied in some contexts, e.g. on policy coherence (Collste et al., 2017).

Qualitatively, there is a visualization of the interconnections between the SDG targets made with the software Kumu (Mohr, 2016) and a qualitative approach with some similarities to the one introduced in this paper by the International Council for Science (ICSU, 2017) and the Stockholm Environment Institute (Nilsson, 2017).

A less systemic approach to identify synergies and trade-offs between the goals analyzes data on indicators for each goal using pairwise correlations (Pradhan et al., 2017).

Finally, there is an approach to quantify and measure changes in indicators using a welfare function that in the end also provides insight regarding correlations between the goals (Barbier and Burgess, 2017).

The iSDG model is based on the Threshold 21 model (T21, <https://www.millennium-institute.org/isdg>) that is adopted to fit the SDGs. It nicely shows interconnections through simulation over time. It does not allow, however, for qualitative exploration of the actual measures and obstacles that are often soft factors such as social, cultural, psychological or political that are difficult to quantify yet crucial for a successful transition towards sustainability.

The Kumu model as well as the ICSU model provide insight but are comparably complicated to edit and the features for analysis are outdated (Sailer, 2012) compared to the

Insight Matrix analysis of the iMODELER software (Neumann, 2015), the tool used for the model we present in this paper.

The ICSU approach is only partly systemic as it merely looks at interconnections between pairs of SDGs, but not in a web across the entire network. However, the input of this approach is profound and meaningful since it is derived from a variety of experts.

Interestingly, Pradhan et al. (2017) in their approach point out correlations between the SDGs' indicators that contradict the ICSU's results. The possibility thus exists that, as they themselves noted, "...correlation does not imply causality..." and "...while the mechanisms generating synergies and trade-offs remain elusive in our analysis, we complement approaches using process-based models by investigating the entire option space in which synergies and trade-offs emerge...". From that regard the present paper offers a tool which can be used to reveal these mechanisms.

A similar opportunity to link the approach from our paper comes with the quantification of the SDG's welfare contribution from Barbier and Burgess (2017). Although the approach presented here differs, it also represents a cause and effect model of the SDGs connecting them to an overall target of well-being.

A literature review (2014–2017) concerning the use of systems approaches for achieving the SDGs revealed that only one study conducted by Obersteiner et al. (2016) uses a true systems approach in which the complexity of differing fields of inquiry and spatial/temporal dynamics are considered. Results of their research show that policies centered around goal 12 (Sustainable Consumption and Production) are the most effective at minimizing trade-offs in terms of environmental conservation initiatives and food prices and can thus be seen as a crucial leverage points if implemented. Although Obersteiner et al. (2016) demonstrate the utility of a systems approach for identifying trade-offs between goals, the model used was created for a specific means and is not designed for easy manipulation to fit other environmental, economic and social contexts.

Along with the study of Obersteiner et al. (2016), five other publications apply approaches concentrated on statistical methods or validation of progress or recommendations (Norheim et al., 2015; Anand and Roy, 2016; Lim et al., 2016; Liu et al., 2016; He et al., 2017). One other study focuses on indicator identification for health-related SDGs (Murray, 2015), while another provided empirically based discussion and critique of health-based indicators (Buse and Hawkes, 2015). Although useful, the complexity of the social, political and environmental spheres in which the SDGs are to be applied calls for a systems approach for informed policy (Obersteiner et al., 2016).

Apart from the relevant academic literature, there are also numerous stakeholder perspectives from which to approach the SDGs which are crucial to their achievement. For example, by analyzing contributions by the private sector, the business perspective is partially captured by the global quality assurance and risk management company DNV GL (2016). Findings from the gamut of such studies can be used to inform analyses more suitable for capturing the inherent complexity of the SDGs.

Collste (2017) argues for an application of the iSDG model on a national or sub-national level by quantifying connections from the qualitative ICSU approach which he considers too vague. He also emphasizes the need to integrate stakeholders in order to achieve the SDGs. Despite these intentions, there remains a gap between qualitative modeling with little analysis

and quantitative modeling with the need for sophisticated formulas and tools. The explorative qualitative cause and effect iMODELER model presented here strike a balance between qualitative and quantitative approaches as the model can easily be intuitively handled and applied. This allows for the explorative identification of actual synergies and trade-offs within a concrete region or nation through participatory stakeholder modeling and subsequent analyses with the iMODELER's "Insight Matrices" (Figure 2 on Page 5).

### 3 The iMODELER software

Qualitative cause and effect modeling allows for a direct visual translation of otherwise spoken or thought arguments such as "more of something leads directly to either more or less of something else." This is depicted by an arrow between two factors, either denoted with a plus or a minus.

The overall model (Figure 1) cannot be read as a single picture as it already contains more than 200 factors with over 450 connections, forming more than 12 million feedback loops. Therefore, there is a direct link to the model through which one has full access and the ability to import it into a freeware version of iMODELER.<sup>1</sup>

The model is best read by changing the perspective from which it is seen by means of placing specific factors as center points. The following screenshots from the model's factors and connections show different perspectives only within the first two of eight total levels. For example, Figure 5 on Page 9 shows the model from the perspective of the factor "limited agricultural production is exported" with two levels of connections.

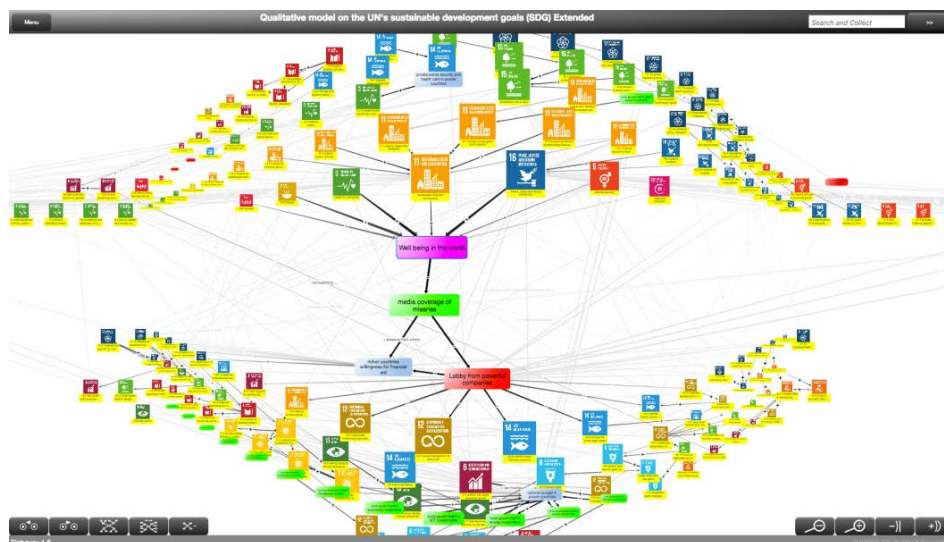


Figure 1. View of the model within which a user can navigate interactively by changing perspectives and using filters

<sup>1</sup> <https://www.know-why.net/model/CaLIsTKbVf7Yg5bm8yRXGyg>

As a starting point and central target of the model we inserted a factor named “Well-being in the world”. The central target is necessary as it allows for the analysis of the model with its “Insight Matrix” (Figure 2) in order to identify and evaluate potential measures which eventually lead to varying degrees of increase or decrease in the target over time. Only the SDGs “End poverty”, “End hunger”, “Health for everybody”, “Sustainable cities and communities” (as it contains housing), “Peace, justice and strong institutions” (as they contain safety), “Gender equality” and “Reduced inequality” are directly connected to the overall target. Although subjective, this selection is widely in synch with Layard’s seven causes of happiness (Layard, 2011). The other SDGs are considered second-order contributing factors that serve these seven SDGs and each other. Their influence on “Well-being in the world” is thus also visualized in an Insight Matrix for this overall target.

Figure 2 shows how to read and interpret the Insight Matrix of a factor. Of course, one can look at the Insight Matrix for any other factor (including each SDG) to see what other factors in the model serve as a lever for concrete action or a hindrance. Also, users of the model may alter the connections in order to directly connect more or less factors to the overall target or any other factor.

The major benefit of this ‘open source’ modeling is its potential to continue reflecting on important factors that define the achievement of the different targets. Through explorative modeling one can ask for each factor four “know-why questions” (Neumann, 2013):

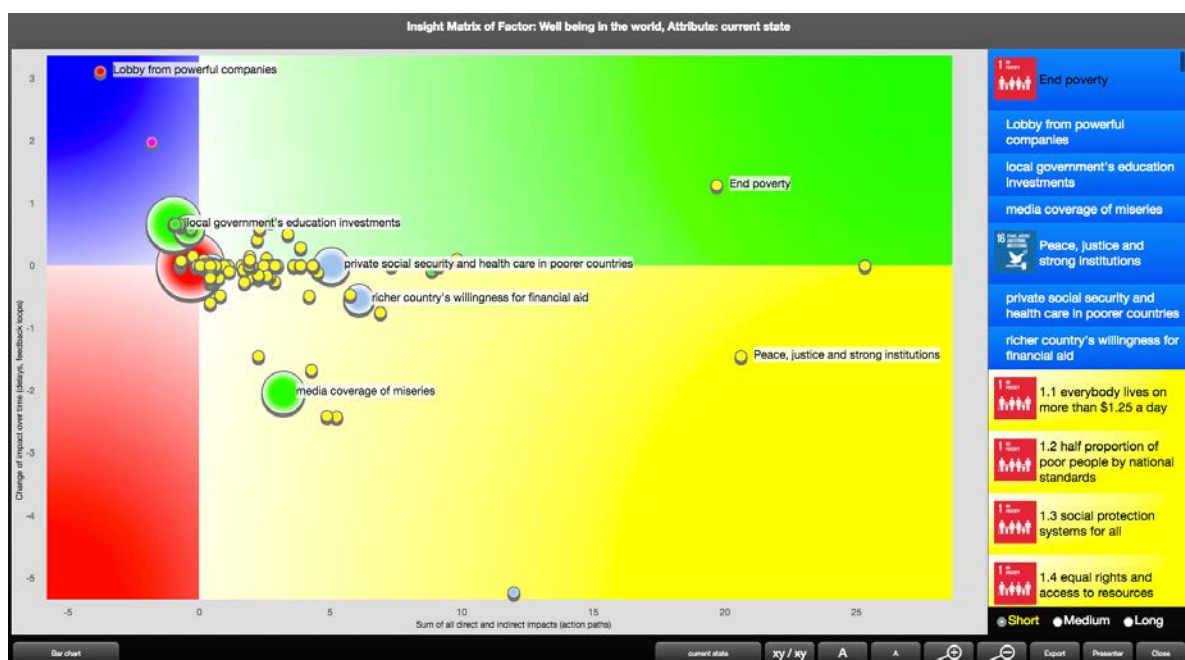


Figure 2. The Insight Matrix from the factor “Well-being in the world” shows on its horizontal axis the effectiveness of other factors either as increasing the “Well-being in the world” or decreasing it. The vertical axis indicates the change of impact over time from short to medium to long term. The diameter of the factors indicate a further attribute, e.g. the current state of a measure, a target, or an obstacle. Note: this matrix should not yet be interpreted, as the connections of the model are not weighted to fit a concrete region or nation.

- What leads directly to more of the factor?
- What leads directly to less of a factor?
- What may lead directly to more of a factor in the future?
- What may lead to less of a factor in the future?

Inclusion of factors from varying disciplines by participatory modeling with experts and stakeholders helps ensure a more robust and realistic model. Therefore, when relevant, technical, organizational, economic, social, cultural, psychological and political fields, among others, should be drawn upon. Figure 3 shows an example of additional factors. One side effect would be that ownership could also be fostered among stakeholders of a possible project (Barrington-Leigh, 2017).

In its first generalized draft the connections between the factors of the model are not yet qualitatively weighted. Qualitative weighting allows the user to define whether one factor's impact onto another is weak or strong compared to that of others, and whether this impact changes from short term to medium term or long term.

Figure 4 shows an example of a qualitative weighting of factors. Note that only incoming connections are compared and therefore weighting should be conducted after all connections are established in the model. One method for weighting is to first determine the strongest impact, then the second strongest, and to continue with the third strongest and all following subsequent factors in this manner. To keep the sum of weights below or equal to 100 is also advisable as this helps maintain consistency and can be more easily interpreted as percentage values for the impacts of each factor. Only after all the connections are weighted should one successively analyze Insight Matrices (see Figure 2) – starting with that of the overall target Insight Matrices from the most important levers and obstacles. This reveals which factors are synergistic (serving several targets) and which have trade-offs or are ambivalent (positive to one goal, negative to another).

Qualitative models as a visualization of arguments from stakeholders and experts allow for inclusion of potentially relevant factors in order to gain a better understanding of a complex system. Reductionist approaches from separate disciplines can struggle to capture this inherent complexity and the necessary multi-dimensional consideration for successful interventions. The conclusions from these qualitative models like the one presented are logically sound (based on abductive logic) and yet they depend on the accuracy of the single pairwise arguments and inclusion of all relevant factors. In this first draft of a model the connections represent commonly accepted relations and arguments based on the author's acquired knowledge. The model provides a template which requires adjustment for use within specific contexts. Literature, expert interviews, workshops, focus groups and a wide range of other research methods can be implemented to further customize and legitimize versions of the model for this purpose.

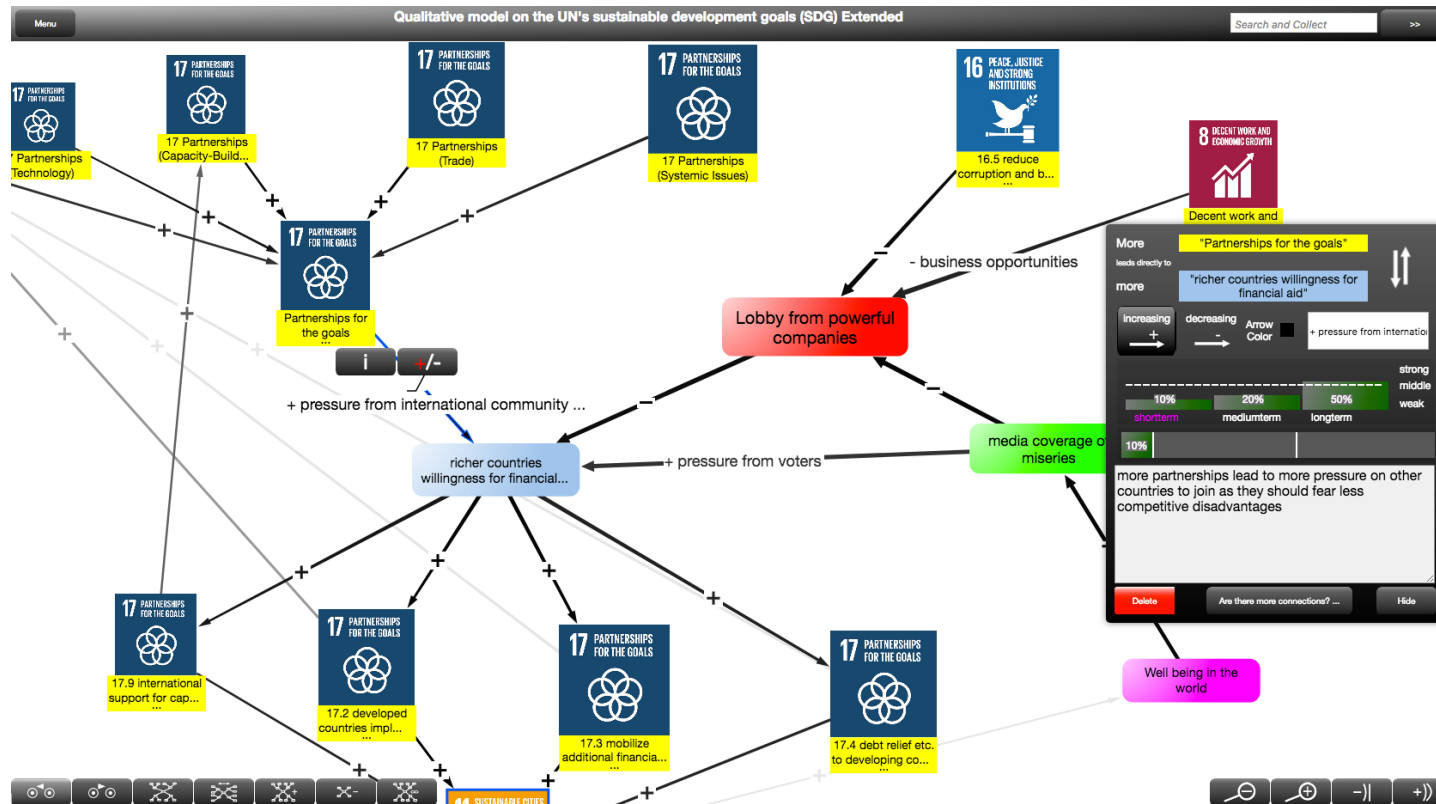


Figure 3. An example of additional factors included by exploratively asking for a wide range of relevant influences. In this case there are three factors that define the willingness of richer countries to supply financial aid: characterized by international and domestic political pressure including that which stems from lobbyists, media, and national budgets (the latter is not shown here). With the properties of the connection from the “Partnership of the goals”, the figure shows how a weighting can change from short term to medium and long term.



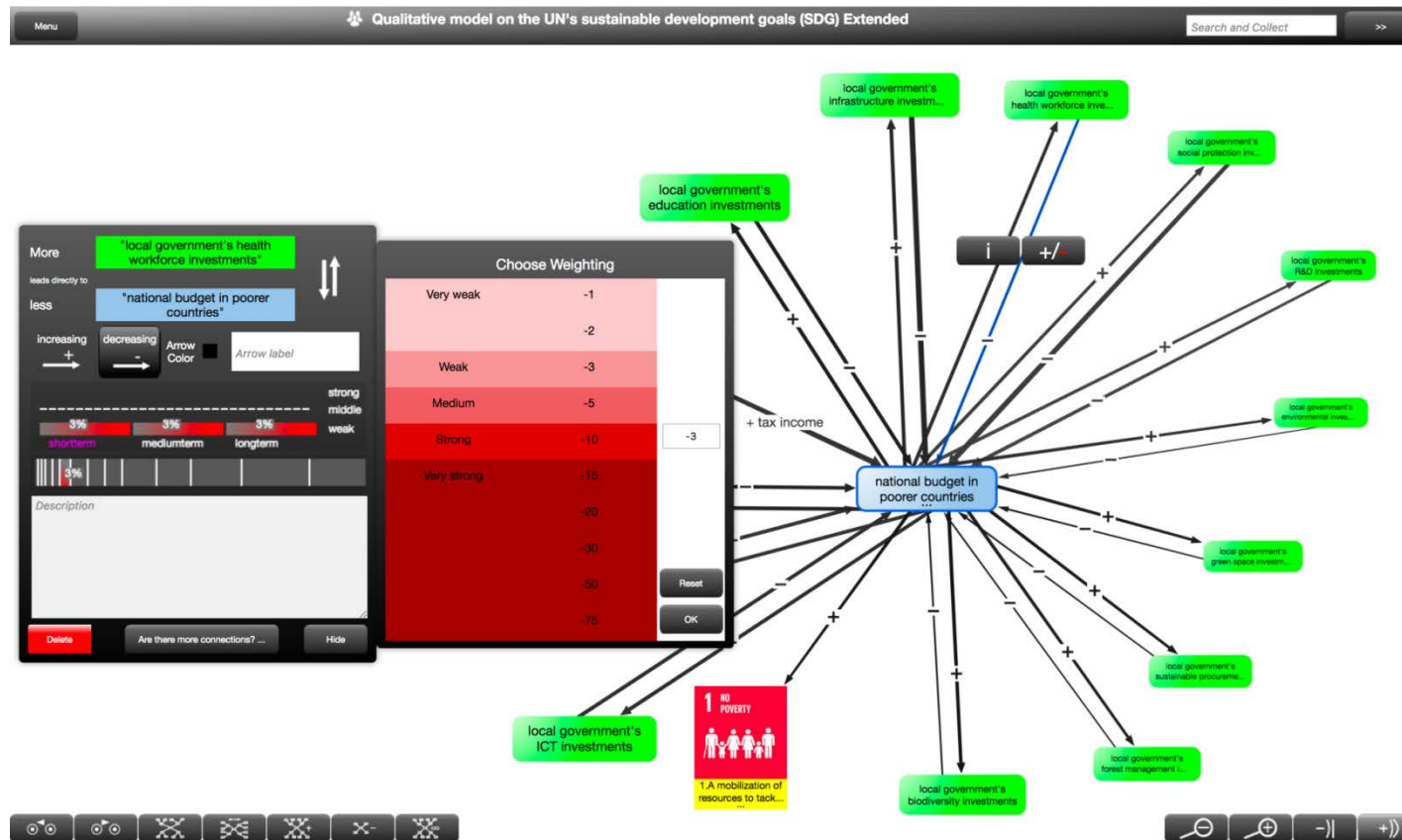


Figure 4. An example of the qualitative weighting of connections

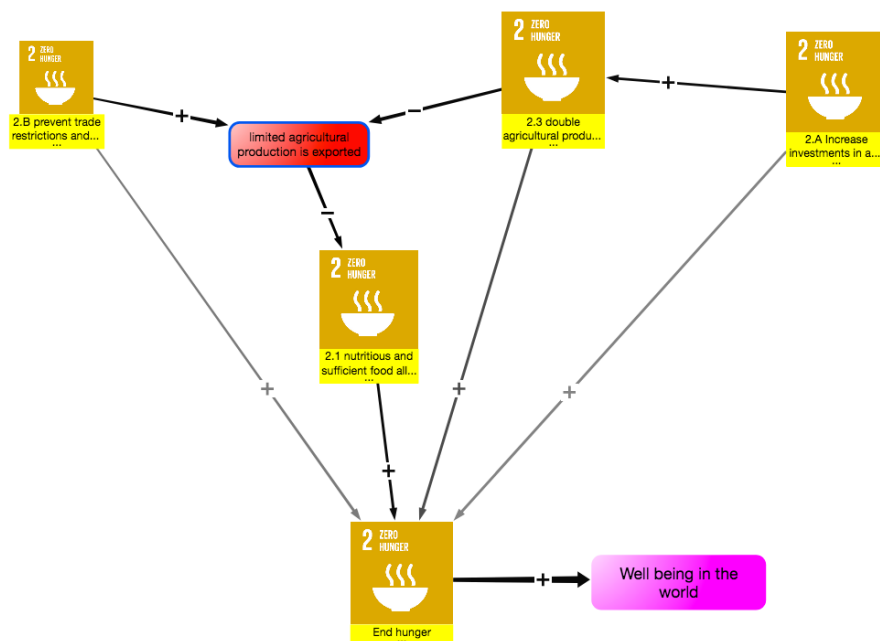


#### 4 Selected views with first insights from the model

The original SDGs are generalized to consider four regions (developed countries, developing countries, least developed countries and small island states), and leave significant room for interpretation and therefore potential weakening of efforts. The resulting language can be seen for example in target 12.7, “Promote public procurement practices that are sustainable, in accordance with national policies and priorities” or target 9.4, “... with all countries taking action in accordance with their respective capabilities”.

The model presented is based on this generalized language at a global scale and case-specific conditions should define connections for its future concrete application. The following selected excerpts from the model should thus be seen as a first step for further examination and a proper weighting in order to determine the synergistic or ambivalent nature of the factors. Figure 5 suggests that, depending on context, there might be a trade-off from more trading and export of agricultural products and the local supply of food.

Figure 6 shows a dialog from iMODELER used to select feedback loops. Highlighted are three examples of potential reinforcing feedback loops and one example of a potential balancing feedback loop. The reinforcing loops show how more “Decent work and economic growth” leads to less “Lobby from powerful companies”, as they profit from the increased demand. With less of this lobbying there is more willingness to help developing countries, leading to more investments and finally more “Decent work and economic growth”. The balancing feedback loop describes a situation in which more investments lead to more productivity which might



*Figure 5.* The prevention of trade restrictions has the potential to end hunger yet by adding another plausible factor (depending on circumstances), it could also mean that scarce biomass production is exported despite it being needed for local food supply. On the other hand, this would be less problematic with successful achievement of target 2.3, implying a sufficient increase in agricultural production.

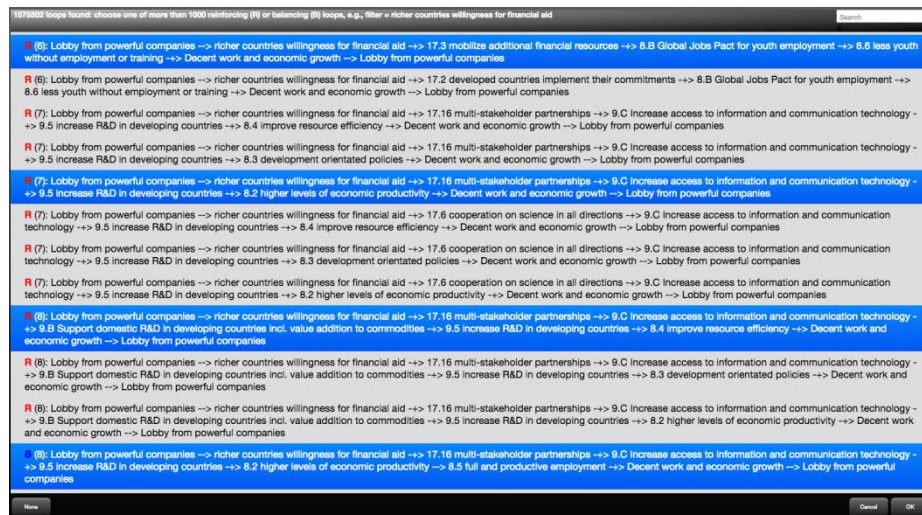


Figure 6. Reinforcing and balancing loops that involve “richer country’s willingness for financial aid”

lead to less jobs and thus less demand. Behind this is the assumption that at a certain point, the individual’s income is no longer consumed and instead floats to the decoupled finance industry (Crouch, 2011).

Figure 7 shows the incorporation in the model of the idea that a decoupling of growth from the use of resources may be unattainable (Jackson, 2009). This is based on the theory that growth alone would imply increased demand and that it would take unprecedented technological developments (e.g. towards a circular economy) to compensate for the otherwise increased need for resources (Meadows et al. 1992). The validity of these connections should be proofed depending on the spatio-temporal context of the model’s application.

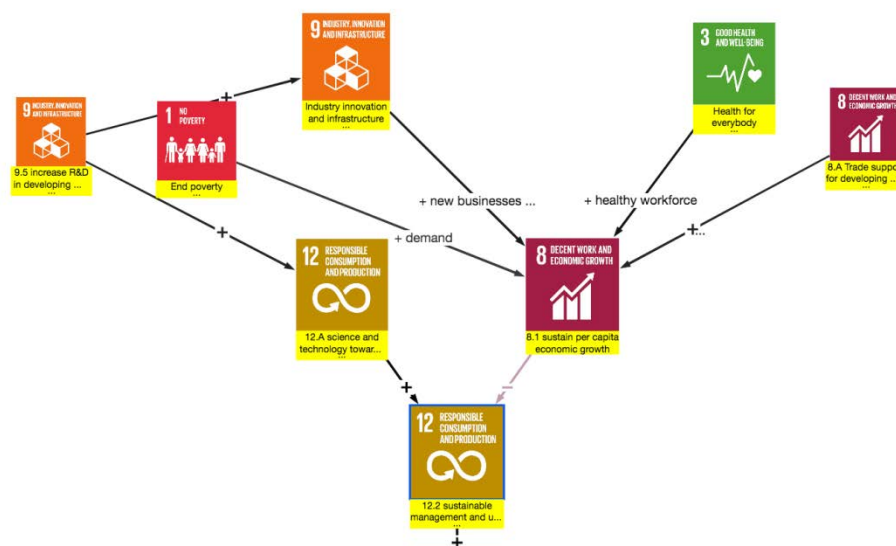


Figure 7. Excerpt from the model showing that “8.1 sustain per capita economic growth” could contradict “12.2 sustainable management and use of natural resources”

Figure 8 shows a similar effect since an increase of productivity e.g. by farm machinery in developing countries as well as by automation and digitization globally might contradict the target of full employment.

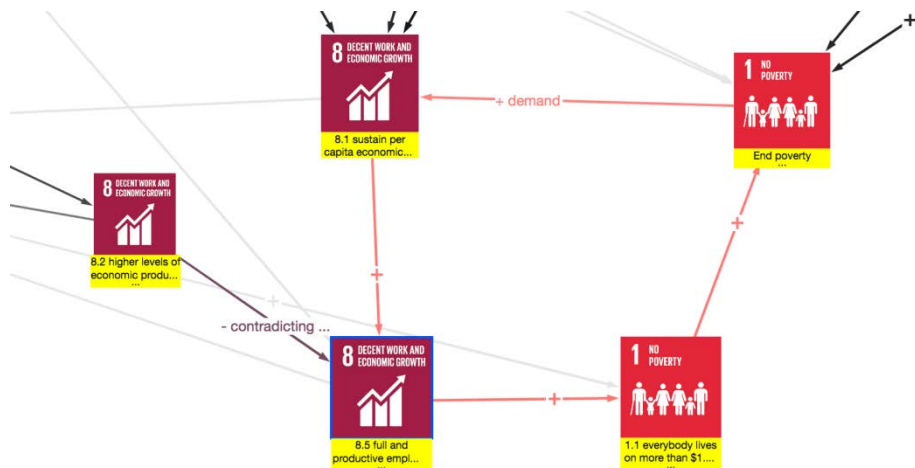


Figure 8. Excerpt from the model showing that “8.1 sustain per capita economic growth” could contradict “8.5 full and productive employment” which could then trigger a reinforcing feedback loop (red) as a downward spiral.

## 5 Application

Figure 8 points to an important systemic perspective only possible with an adequate tool to enable a systems approach. Behind the assumption that productivity is beneficial is a rather classic paradigm of economic growth (Beinhocker, 2007; Jackson, 2009; Crouch, 2011) that suggests that there is an endless increase of more persons consuming more service units (Schmidt-Bleek, 2000). Instead we have to consider that more people asking for more service units (e.g. energy production, whether from renewables or fossil fuels) can sooner or later increase resource prices. Although this increase means economic activity on one hand, the accompanying automation and digitization can also lead to a reduction in jobs and “decent work”. There is little left for the victims of this disruptive prospect of increased productivity and the most vulnerable are disproportionately impacted. The specialists who profit from these developments will not spend all their money fostering labor intensive services – instead larger portions of money will vanish in the financial industry (Crouch, 2011). Although neither the model provided nor the SDGs feature these likely social tensions explicitly, such dynamics are important considerations for model specification and indeed practitioners generally interesting in effectuating the SDGs.

Initial findings from a quantitative model created by the author and based on participatory stakeholder modeling workshops show how an increase of productivity in the agricultural sector of a developing country can potentially lead to a decrease in employment which cannot be compensated by any other domestic industry as a result of competition with developed

countries. Therefore, in this case a gain in productivity could only selectively increase income, which is often subsequently spent on imported goods and thus leaves less money for the domestic economy.

The application of the model to fit a concrete region or nation should cover these systemic potentials and pitfalls and consider improving productivity without sacrificing gainful employment and the strength of the domestic economy of developing countries, thereby limiting the outflow of money and resources to developed countries. This potentiality needs a more differentiated modeling with additional factors and appropriate weighting of connections to fit a concrete region or nation.

It should also be noted that adding new factors which represent policy interventions into regionally adjusted models could also provide first insight into their effectiveness. A pertinent current example which could conceivably support the successful achievement of the SDGs is that of a universal basic income, an idea also being proposed at the global level ([www.globalincome.org](http://www.globalincome.org)). This is a relevant example as such an intervention would surely have unanticipated systemic effects in our globalized world, whether they be positive or negative, well beyond the obvious or immediate purpose (Van Parijs and Vanderborght, 2015).

However, the SDGs do not yet consider a global universal income ([www.globalincome.org](http://www.globalincome.org)) or similar.

In order to provide ideas about how to apply this model and the method of explorative qualitative – and in this case also collaborative – modeling, we have combined the SDG model with a cause and effect model based on (collaborative) output from a workshop conducted by the authors in Ghana with participants representing farmers, researchers, and private entities.

Figure 9 shows a model extracted from the original created in the workshop. This model focuses on “Quality and quantity of water in rivers”. We applied the already mentioned four “know-why questions” to exploratively understand the challenge of fresh water supply in the context of illegal mining activities.

Inserting the Ghana model into the SDG model, some major challenges stemming from the environment, social circumstances, the economy, and the current political situation arise. The added value of connecting it to the overall model of SDGs (Figure 10) and their targets is that core roots to some of the challenges or synergies, as by a means of support from other targets and their measures, could be revealed.

Whether one connects a separated model to the SDG model afterwards or works directly within the SDG model should depend on various aspects. For example, if expert workshops are used as a research method, time limitations could inhibit adequate explanation of the existing SDG model to participants. Therefore there may also be instances in which an individual target from the SDG model is taken as a starting point for model development or, such as in this case, a quite specific aspect is reflected on and at a later stage connected to SDG target factors. In this model the connection was made from the Ghana model’s factor “Quality and quantity of water in rivers” and the SDG model’s factor “15.1 Focus on freshwater ecosystems”.



Figure 9. Model describing influences on quality and quantity of water in rivers in Ghanaian context. The link to the model: <https://www.know-why.net/model/CJsA612RuvvYz2wZCB2NVJw>

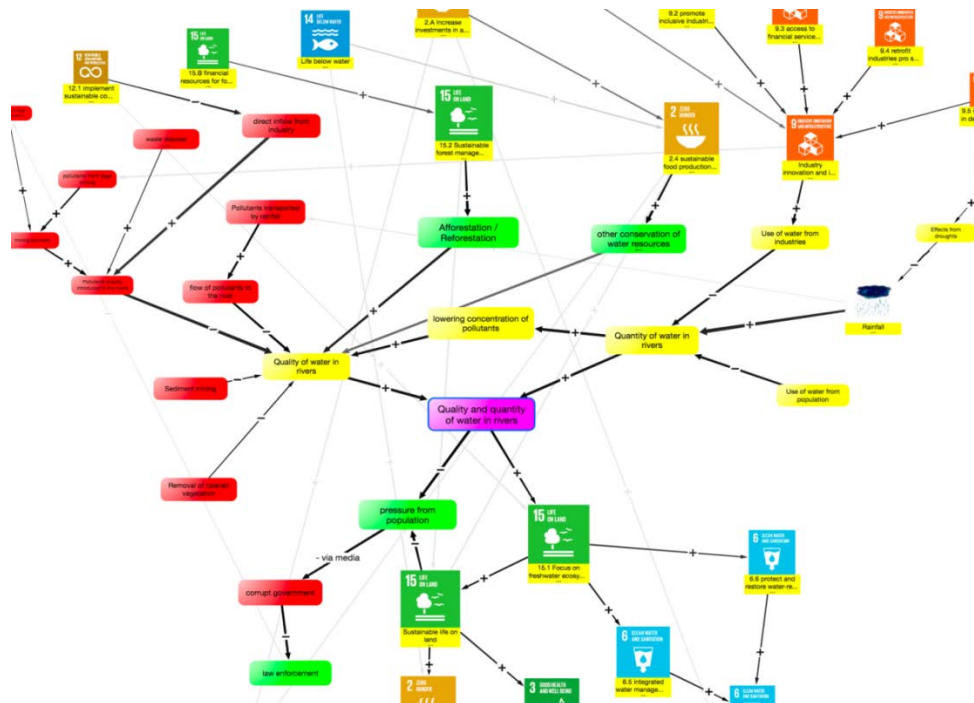


Figure 10. Excerpt showing the integration of the Ghana model into the SDG model. The model can be accessed through the link: <http://www.imodeler.info/ro?key=CPFrzJ4XdToSe7rwU1H8nNw>



Using the explorative questioning technique of the aforementioned know-why questions helps elicit potentially relevant technical, financial, cultural, political, legal, or psychological factors. One should refrain from descriptively picking existing factors from the SDG model presented and instead only use them for brainstorming. It is necessary to repeat the process of first exploratively asking the four “know-why-questions” for context specific influencing factors.

Figure 11 shows the "Tornado chart" of the Insight Matrix for the factor “Quality and quantity of water in rivers”. It already shows numerous targets from the SDGs that also influence the quality and quantity of water in rivers in Ghana. Many of the negatively influencing factors on the left of the tornado chart may not be intuitively obvious, but an analysis of the cause trees (iMODELER offers a “Show why” button for this) shows that they are influenced by an increase of industrial activity that potentially reduces the quantity and possibly diminishes the quality of river water. However, with more time and depth, the factors related to industry could be differentiated in order to distinguish between different kinds of industries and their effects, thereby going beyond this generalized perspective on the quality and quantity of water.



Figure 11. Tornado chart of the Insight Matrix for the factor “Quality and quantity of water in rivers” showing also the impact from the SDGs and their targets.

To apply the explorative cause and effect modeling of the SDGs or continue with the template at hand adding arguments requires focusing on a specific case at a less aggregated level. The strength of this model is that everybody can use it to include her or his arguments and thereby explore the interconnections and case-specific outputs. The template helps to interconnect new arguments with given SDGs and the whole set of their targets. For both, the consideration of additional crucial factors in order to grasp the mechanisms and processes behind the development of the SDGs, as well as for the weighting of their connections, requires the use of further methods and contributions of experts and stakeholders.

In order to create a generalized world one would need to at least distinguish unique factors and connections for the aforementioned four regions (developed countries, developing countries, least developed countries and small island states). Despite this attempt, there would remain contextually dependent interconnections and the model would require further factors to be exploratively added in order to understand the mechanisms and processes.

Yet, if such a world model is the objective, input could come from numerous such models on the iMODELER sharing platform [www.know-why.net](http://www.know-why.net). If ideas for potentially relevant factors are needed while modeling one can ask for suggestions regarding connections from this repository of models and connections (Figure 12).

An equally interesting application of this model would be its use in a social lab setting with stakeholders and experts, possibly in a collaborative explorative modeling workshop where participants can use personal computers, tablets or smartphones to edit the same model and build it together. Formats such as world café sessions using the four know-why questions to add crucial factors and adopt the weighting of connections to the concrete region or nation featured with the model would be well-suited for application of this tool. Points which emerge during discussion can be immediately captured and the sum of arguments analyzed in order to come up with concrete actions relevant to achieving the SDGs.

## **6 Discussion**

It should be noted that data would be of limited help for validating interconnections on any necessarily aggregated level since both the verification and the falsification of interconnections could be the result of phenomena outside a system's boundaries. Nevertheless, checking against data could help to improve the model by identifying decisive additional factors and including them.

Another relevant application of data from correlations (Pradhan et al., 2017) would be to build a model based on the strengths of identified correlations. However, this would not be insightful unless the modeler checks for redundancies from existing indirect connections and addresses other common fallacies relevant to attributing correlation with causation. Mistakenly linking factors in a cause and effect model would lead to erroneous results.

This tool is only an example of modeling and should be recognized as subjective, reductionist and of abductive logic (Fabricius, 2016), with quality depending on the input from experts and stakeholders and with results that need to be revised over time. However, such an endeavor is imperative for gaining a better understanding of a possible future development.



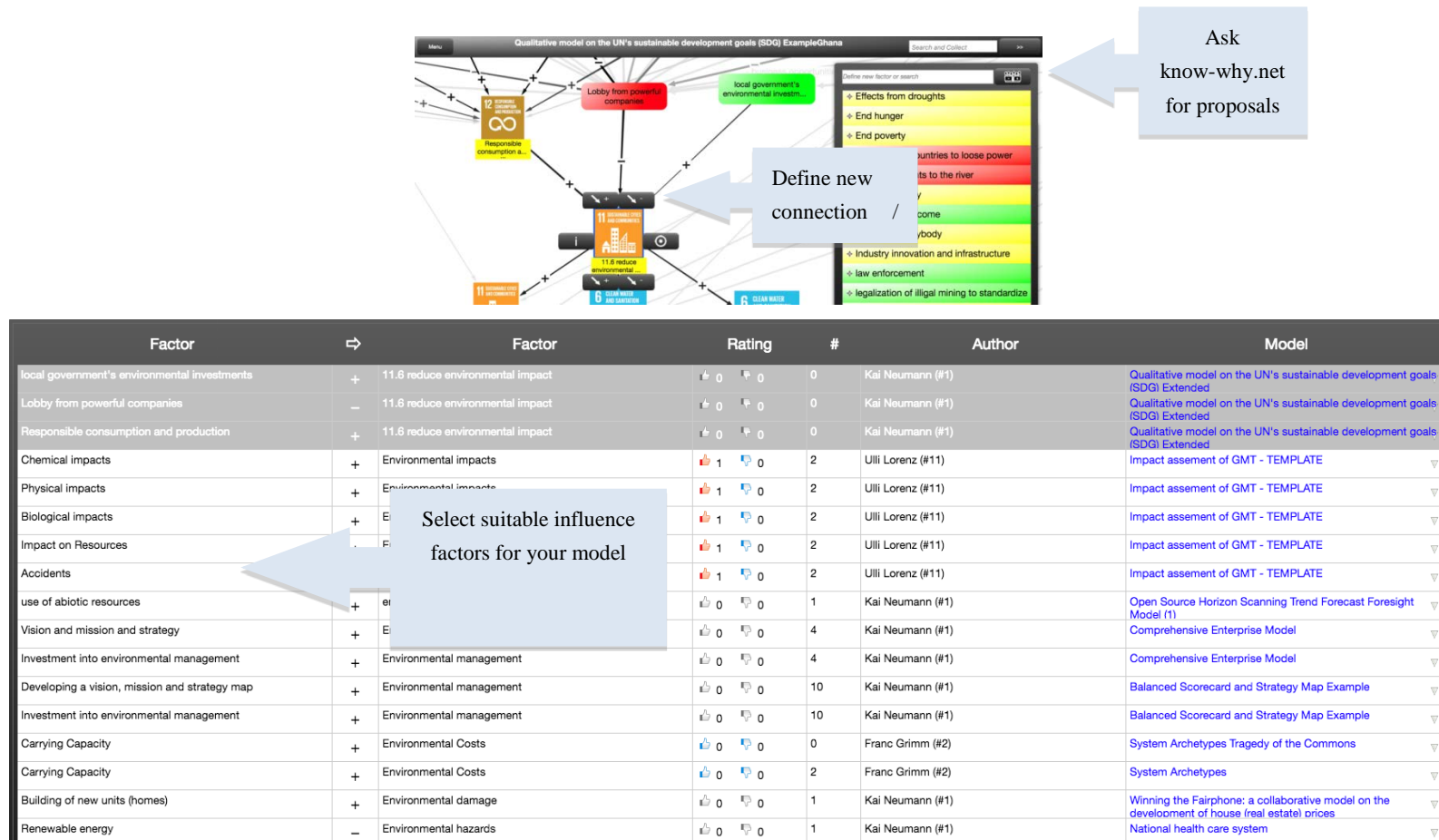


Figure 12. Clicking on the button next to the editing field of a new connection will generate proposals for influencing factors that are connected to similar factors from other models on the know-why.net platform.

## 7 Conclusions

Whether it is for only one SDG, several specific ones, or indeed the entire set, modeling will provide useful insights, allow for the discovery of potential synergies and trade-offs or ambivalences, and create ownership for stakeholders of the transition towards sustainability. Our vision for the application of this approach: to foster a better understanding of the actual challenge while integrating stakeholders and experts to enable idiosyncratic hard and soft factors to be systemically considered.

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